# METHOD AND APPARATUS FOR MAKING SEMI-SOLID METAL SLURRY

## BACKGROUND OF THE INVENTION

### Field of the Invention

The present invention relates to a method and apparatus for manufacturing a semi-solid metal slurry, and more particularly to a method and apparatus for manufacturing a semi-solid metal slurry having a uniform spherical structure through a simple process.

### Description of the Related Art

In general, semi-solid metal forming is a method for forming metal or a metallic composite material in a range of temperature within which a liquid phase and a solid phase exist together. The semi-solid metal forming technology has been studied and developed for practical use, as a new technology, which can relieve drawbacks while maximizing advantages of a casting method for forming metal in a molten state and of a forging method for forming metal in a solid state. In order to effectively form the semi-solid metal, it is important to manufacture slurry having an initial structure with spherical particles uniformly distributed therein and without dendrites.

Accordingly, various methods and apparatuses have been suggested for manufacturing the semi-solid metal slurry using the semi-solid metal forming method. As for a representative method among the conventional technologies, a method is well known in the art, in which the dendrites are destructed into a spherical structure using a shear stress through mechanical or electromagnetic agitation during solidification of molten metal.

However, according to the conventional method and apparatus for manufacturing the semi-solid metal slurry, the shear stress is used for forming the spherical structure by destructing the dendrites. That is, in the conventional method and apparatus, since force, such as vibration, is applied to the dendrites after some portion of the molten metal has a temperature lowered below a liquidus line of the metal, it is difficult to achieve entirely uniform and fine structure in an initial solidification layer and metallic structure formed therefrom due to non-uniformity of the temperature within a furnace. Additionally, if an injection temperature into the furnace having the molten metal is not controlled, the non-uniformity of the structure becomes serious due to a temperature difference between a wall of the furnace and the center of the furnace.

In order to solve the problems as described above, one of the conventional technologies comprises: a molten metal

injection process 110 for injecting molten metal into a furnace in a state of being slanted without application of an agitation force as shown in (a) of Fig. 7; a cooling process 120 for cooling the furnace by blowing cooling air to an outer wall of the furnace in a cooling furnace and the like in order to reduce a temperature difference between an outer portion and an internal portion of the molten metal as shown in (b) of Fig. 7, thereby forming dendrites in a portion of the molten metal contacting the outer wall of the furnace; a high frequency heating process 130 for heating the furnace to an appropriate temperature using a high frequency wave as shown in (c) of Fig. 7, thereby forming uniform structures by reducing the temperature difference between the outer portion and the internal portion of the molten metal due to growth of α-phase according to a principle of diffusion; and separating manufacture semi-solid metal slurry from the furnace as shown in (d) of Fig. 7, followed by forming the semi-solid metal slurry into a desired shape.

However, according to this method, since the semi-solid metal slurry is manufactured through several steps, it is troublesome and time consuming, thereby remarkably reducing the productivity of the semi-solid metal slurry.

## SUMMARY OF THE INVENTION

Therefore, the present invention has been made in view of the above problems, and it is an object of the present invention to provide a method for manufacturing a semi-solid metal slurry having a uniform spherical structure through a simple process.

It is another object of the present invention to provide an apparatus for manufacturing a semi-solid metal slurry, designed to have a united simple construction from supply of molten metal to forming of the semi-solid metal slurry, thereby allowing convenient manufacturing of the semi-solid metal slurry having a uniform spherical structure.

It is still another object of the present invention to minimize a temperature difference of molten metal fed into a furnace.

It is still another object of the present invention to perform rapid cooling of the molten metal with greater efficiency.

It is yet another object of the present invention to uniformly distribute the slurry in a slurry-storing container.

In accordance with an aspect of the present invention, the above and other objects can be accomplished by the provision of a method for manufacturing a semi-solid metal

slurry having a uniform spherical structure, comprising the steps of: feeding molten metal into a furnace; agitating the molten metal in the furnace by application of an electromagnetic field through an electromagnetic agitator to remove a temperature difference in the molten metal while suppressing growth of dendrites; performing rapid cooling to remove a specific heat and latent heat of the molten metal emitted from the furnace in a cooling part to prevent oxidation of the molten metal in an inert atmosphere while preventing dendrites from being formed therein; and storing the cooled semi-solid metal slurry dropped through a guide member positioned at an angle such that the semi-solid metal slurry is uniformly distributed in a slurry storing container.

The method may further comprise the step of controlling an internal temperature of the molten metal using a temperature controller according to a temperature of the molten metal fed into the furnace and an atmospheric temperature in the furnace.

In accordance with another aspect of the present invention, an apparatus for manufacturing a semi-solid metal slurry having a uniform spherical structure is provided, comprising: a furnace formed of a refractory material and having a housing formed at an upper portion thereof such that molten metal is fed into and discharged from the

housing; an electromagnetic agitator for generating an electromagnetic field through application of electricity to an outside of the furnace; a cooler for performing rapid cooling of the molten metal discharged below a discharging path of the furnace; a guide member positioned at an angle such that cooled slurry is guided along the guide member to a supporting frame equipped below the cooler; and a storing part equipped below the guide member for uniformly storing the slurry dropped along the guide member.

The apparatus may further comprise a temperature controller provided in the furnace for controlling an internal temperature of the molten metal according to a temperature of the molten metal fed into the furnace and an atmospheric temperature in the furnace.

The temperature controller may comprise a temperature sensor, and a heating member for generating heat according to a signal from the temperature sensor.

The cooler may comprise a space defined between an inner wall and an outer wall of the cooler such that a path is formed through the center of the cooler, and a supply pipe connected from one side of the outer wall to the space, the inner wall being formed with a plurality of injection holes communicated with the space.

The electromagnetic agitator may be equipped to the outside of the furnace and the cooler.

The storing part may comprise a slurry-storing container for containing the slurry dropped thereto, and a circulating member for circulating the slurry so that the slurry is stored uniformly within the slurry-storing container.

The circulating member may circulate the slurry-storing container in a predetermined locus by means of an input program.

The slurry-storing container may be formed of a ceramic material having a low thermal conductivity.

## BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a schematic block diagram illustrating a method for manufacturing a semi-solid metal slurry according to the present invention;

Fig. 2 is a longitudinal cross-sectional view illustrating major components of an apparatus for manufacturing a semi-solid metal slurry according to the present invention;

Figs. 3 to 6 are optical micrographs showing several structures of the semi-solid metal slurry manufactured by the method and apparatus according to the present invention; and

Fig. 7 is a flow diagram illustrating a conventional method for manufacturing a semi-solid metal slurry.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments will now be described in detail with reference to the accompanying drawings.

Fig. 1 is a schematic block diagram illustrating a method for manufacturing a semi-solid metal slurry according to the invention.

The method of the invention can manufacture a semi-solid metal slurry having a uniform and non-directional spherical structure, which provides excellent results in tests for workability for forming a complicated shape, dimensional precision, formability, heat treatment, pressure resistance associated to a bubble defect, while providing excellent productivity, and which has excellent wear resistance, elongation, hardness, and tensile strength.

The method of the invention comprises step S1 of feeding molten metal into a furnace through a pouring port of a well-known ladle; step S2 of agitating the molten metal

in the furnace by application of an electromagnetic field through an electromagnetic agitator, thereby removing a temperature difference in the molten metal so as to allow uniform temperature distribution in the molten metal while suppressing growth of dendrites; step S3 of performing rapid cooling to remove a specific heat and latent heat of the molten metal emitted from the furnace in a cooling part to prevent oxidation of the molten metal in an inert atmosphere while preventing the dendrites from being formed therein; and step S4 of storing the cooled semi-solid metal slurry dropped through a guide member positioned at an angle such that the semi-solid metal slurry is uniformly distributed in a slurry storing container.

The method of the invention further comprises step S1a of controlling an internal temperature of the molten metal using a temperature controller according to a temperature of the molten metal fed into the furnace and an atmospheric temperature in the furnace. Accordingly, since the molten metal can be controlled to have a predetermined temperature through step S1a, loss in initial heat capacity can be minimized upon feeding the molten metal again to the furnace.

Fig. 2 is a longitudinal cross-sectional view illustrating major components of an apparatus for

manufacturing a semi-solid metal slurry according to the present invention.

The apparatus of the invention can manufacture semi-solid metal slurry having a uniform and non-directional spherical structure, which provides excellent results in tests for workability for forming a complicated shape, dimensional precision, formability, heat treatment, pressure resistance associated with bubble defects, while providing excellent productivity, and which has excellent wear resistance, elongation, hardness, and tensile strength.

The apparatus of the invention comprises: a furnace 10 formed of a refractory material and having a housing 1 formed at an upper portion thereof such that molten metal is fed into and discharged from the housing; a typical electromagnetic agitator 20 for generating an electromagnetic field through application of electricity to an outside of the furnace so as to allow a uniform distribution of a temperature in the molten metal fed into the furnace while suppressing growth of dendrites; a cooler 30 for performing rapid cooling of the molten metal so as to remove a specific heat and latent heat of the molten metal discharged below a discharging path 12 of the furnace 10 while preventing oxidation of the molten metal due to an inert atmosphere; a funnel-shaped guide member 40 positioned at an angle such that cooled slurry is guided along the

guide member to a supporting frame equipped below the cooler 30; and a storing part 50 equipped below the guide member 40 for uniformly storing the slurry dropped along the guide member.

Preferably, the apparatus further comprises a temperature controller 60 provided in the furnace 10 for controlling an internal temperature of the molten metal according to a temperature of the molten metal fed into the furnace and an atmospheric temperature in the furnace. For this purpose, the temperature controller 60 comprises a typical temperature sensor (not shown), and a heating member (not shown) for generating heat according to a signal from the temperature sensor.

Accordingly, the temperature controller 60 allows variation in temperatures of the internal of the furnace into which the molten metal is poured, and of the molten metal poured into the furnace to be minimized, thereby keeping optimal conditions for manufacturing the semi-solid metal slurry.

In particular, the temperature controller 60 also acts to minimize initial loss of heat capacity upon feeding the molten metal again to the furnace.

The cooler 30 comprises a space 35 defined between an inner wall 34 and an outer wall 36 of the cooler 30 such that a path 32 is formed through the center of the cooler 30

in order to allow the molten metal discharged from the discharging port of the furnace to pass through the path 32, and a supply pipe 36a formed at one side of the outer wall 36 so as to be communicated with the space. Preferably, the inner wall 34 is formed with a plurality of injection holes 34a, which are communicated with the space 35, such that a refrigerant is supplied to the molten metal passing through the path 32, thereby allowing rapid cooling of the molten metal.

The electromagnetic agitator 20 is preferably equipped to surround the outside of the furnace 10 and the cooler 30, and then generates the agitating force by virtue of the electromagnetic field, thereby preventing the dendrites from being formed not only in the molten metal within the furnace but also in the molten metal passing through the cooler.

The storing part 50 comprises a slurry-storing container 52 for containing the slurry dropped thereto, and a circulating member 54 for circulating the slurry by use of a well-known turntable or an automatic machine so as to uniformly store the slurry within the slurry-storing container. The circulating member 54 preferably circulates the slurry-storing container in a predetermined locus by means of an input program.

Accordingly, it is possible to provide uniform distribution of the slurry within the slurry-storing container.

The slurry-storing container 52 is preferably formed of a ceramic material having a low thermal conductivity, thereby minimizing variation in temperature of the slurry stored within the slurry-storing container.

Figs. 3 to 6 are well-known optical micrographs showing several structures of the semi-solid metal slurry manufactured by the method and apparatus according to the present invention, in which Fig. 3 is a picture showing a structure of a lower portion of the slurry, Fig. 4 is a picture showing a structure of an upper portion thereof, Fig. 5 is a picture showing a structure of an inner portion thereof, and Fig. 5 is a picture showing a structure of an outer portion thereof. As shown in Figs. 3 to 6, it can be appreciated that the semi-solid metal slurry has a uniform spherical structure in the inner and outer portions of the slurry as well as from the lower portion to the upper portion of the slurry.

Accordingly, the present invention can ensure not only conditions for providing an entirely uniform and fine structure to the semi-solid metal slurry by maintaining a constant temperature of the molten metal poured into the furnace while agitating the molten metal below a temperature

of the liquidus line by means of the electromagnetic field, but also conditions for maintaining the constant temperature without the temperature difference between the inner portion and the outer portion of the slurry stored within the slurry-storing container, thereby allowing convenient manufacturing of the semi-solid metal slurry within a single united apparatus while providing an entirely uniform spherical structure to the semi-solid metal slurry through a simple manufacturing process.

As apparent from the above description, the method and apparatus according to the invention allows convenient manufacturing of the semi-solid metal slurry within a single united apparatus while providing an entirely uniform spherical structure to the semi-solid metal slurry through a simple manufacturing process, thereby maximizing the productivity of the semi-solid metal slurry having the uniform spherical structure while remarkably reducing manufacturing costs thereof.

Moreover, the temperature difference of molten metal fed into the furnace can be minimized, thereby providing an optimal state for manufacturing the semi-solid metal slurry.

Moreover, the rapid cooling of the molten metal can be efficiently performed by use of the double pipe-shaped cooler, thereby preventing the oxidation of the molten metal

due to the inert atmosphere while suppressing formation of the dendrites.

Moreover, uniform distribution of the slurry stored within the slurry-storing container can be ensured by means of the circulating member of the storing part.

Although the preferred embodiments of the present invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.